Beam-Lead Devices and Integrated Circuits

This correspondence describes a new semiconductor device structure and its application to high-frequency silicon switching transistors and ultra-high-speed integrated circuits. The technique of fabricating the structure consists of depositing an array of thick contacts on the surface of a slice of standard planar-oxidized devices and then removing the excess semiconductor from under the contacts, thereby separating the individual devices and leaving them with semirigid beam-leads cantilevered beyond the semiconductor. The contacts serve not only as electrical leads but as the structural support for the device as well, hence, the name beam-leads.

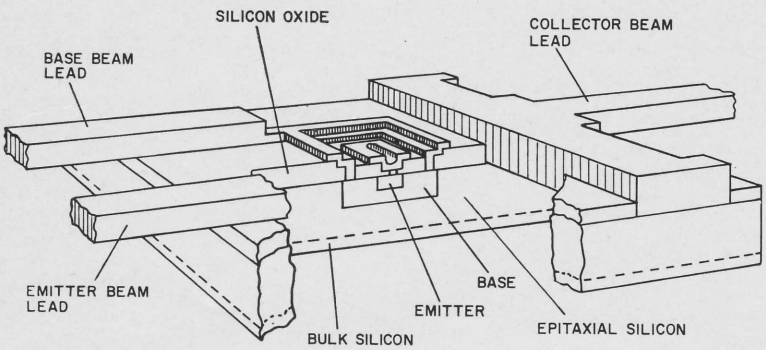

Fig. 1. Cut-away cross section of high-frequency beam-lead switching transistor.

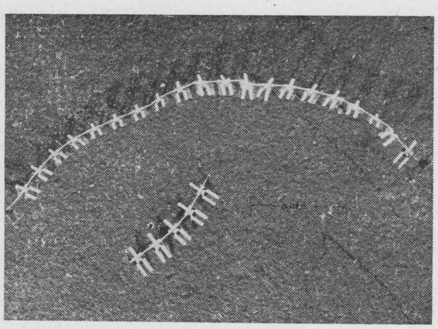

Fig. 2. Photo of string of beam-lead transistors.

Figure 1 is a cross-sectional drawing of a high-speed silicon switching transistor with beam-leads. The metallized emitter and base fingers are formed thinner than the beam leads to permit the close electrode spacing necessary for high-frequency operation.

The beam leads can be used to fasten the individual devices to a substrate by bonding the leads to metallized areas on the substrate. Thermocompression bonding or welding may be used. There is no necessity for chip brazing or individual wire bonding with this device. In addition, the beam-leads impose no electrical penalty over conventional chip-and-wire techniques of fabrication.

Figure 2 shows a face view of a string of beam-lead transistors fabricated with a connecting strip from collector to collector. This method allows devices to be simply handled in large numbers for feeding, testing, and bonding. As required, one device is readily bonded to a substrate and broken from the string. Since the string is initially fabricated as an array on the silicon slice, all dimensions are held to close tolerances; any lead is precisely oriented with respect to another, facilitating multiple lead bonding.

After bonding, transistors like those shown in Fig. 2, have been centrifuged to 135 000, g's without failure. Calculations show they should withstand twice this acceleration. The leads have been flexed over 20 times by bending 90° over a 2 mil radius (a 1.5-mil gold wire broke at 17 bends). This contact system has also been subjected to severe environmental stress. Transistors have been aged in 360°C steam (700-mm Hg pressure) for over 1000 hours with no apparent degradation; changes in contact resistance are under 1 ohm (ΔV_{be} less than 0.01 volts at 10 mA). Thermal resistance of this transistor is 1 C/°mw, leading to a junction rise of approximately 2°C when the device is fully saturated with $I_c = 10$ mA. For higher power requirements, the beam leads can be widened to provide proper heat transfer.

The technique is readily extended to and has many applications in integrated circuits.

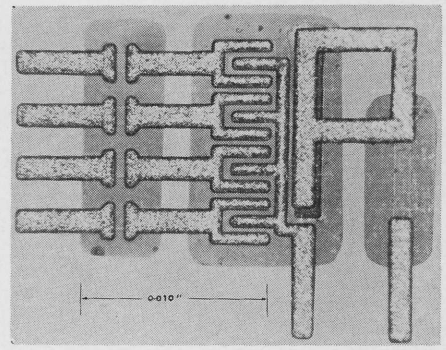

Fig. 3. Photo of isolith (face view).

Figure 3 is a photo of an isolated monolithic integrated circuit ("isolith"). The circuit is a four-input DCTL gate, and consists of 4 *n-p-n* transistors (common emitter and collector), 4 diffused base input resistors (200 ohms), and a diffused collector-load resistor (840 ohms). The input resistors are in one block of material, the transistors in a second, and the load resistor the third. Each block is isolated from the next by the removal of silicon from between blocks. The isolith pictured will also survive 135 000 g's centrifuging. The speed of the circuit is equivalent to circuits wired with discrete chips.

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